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COMPOSITION AND VARIATION OF WASTE WATER FROM FOOD-PROCESSING PLANTS

ARS 41-186
March 1972

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PROCUREMENT SECTION
CURRENT SERIAL RECORD

SOIL AND WATER
CONSERVATION
RESEARCH DIVISION

AGRICULTURAL RESEARCH SERVICE • U.S. DEPARTMENT OF AGRICULTURE

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Composition and Variation of Waste Water From Food-Processing Plants[1]

George A. Pearson, Willem G. J. Knibbe, and Harvey L. Worley[2]

SUMMARY

A survey was conducted to determine the chemical composition and variability of the waste water from 20 plants processing nine food products. In general, the composition of the waste water samples varies greatly for individual products, for different plants processing the same product, and for time of sampling—even for hour to hour intervals—in a single product.

Part of the variability is attributable to the processing procedure. For example, operations such as blanching, quality grading, and lye-peeling involve the use and periodic dumping of vats or tanks containing high concentrations of salts or organic residues.

The results of the survey indicate that the chemical composition of waste water cannot be predicted with certainty. However, some generalizations can be made. The waste waters from plants processing tomatoes, corn, and lye-peeled sweet potatoes are generally the highest in solids and COD. The waste water from plants processing peas, lima beans, and lye-peeled sweet potatoes are highest in electrical conductivity (salinity) and sodium.

INTRODUCTION

The Water Quality Act of 1965 restricts the indiscriminate discharge of wastes into surface waters. This restriction has forced municipalities and industries, including food processors, to adopt waste water treatment methods such as lagoons, trickling filters, chemical precipitation, and flood and sprinkler irrigation.

Many food-processing plants are located in rural areas near small towns. In most cases, the limited waste water treatment facilities in the town cannot handle the large volumes of water and high concentrations of organic matter released by the processing plant during the relatively short processing season. Therefore, many food processors must resort to some other system of waste water treatment. Irrigation would be an alternate system available to a processor located in a predominantly agricultural area. However, the feasibility of such a system would depend on the composition of the waste water. The ionic composition of the waste water, because of its effects on plants and soil, is more important than the amount of organic matter in the water.

Many reports in the literature give concentrations of organic matter and solids in municipal waste water. However, relatively few reports give data for the composition of waste water from food-processing plants, and most of these have emphasized the organic matter content rather than the ionic composition. Of 46 papers reporting data on food-processing waste water, only eight papers gave concentrations for any ionic constituents and only one of these gave values for sodium, calcium, and magnesium together.

Because information concerning the ionic composition of waste water is extremely meager, a survey was conducted in 1967-69 to determine the characteristics, particularly the ionic constituents, of waste water from food-processing plants. The results of the survey are discussed in this report.

For meaningful results, the survey required access to a large number of plants processing a wide variety of products. Accordingly, the Mid-Atlantic Food Processors Association, Inc.[1] provided access to approximately 75 of the more than 200 processing plants in Delaware, Maryland, New Jersey, and Virginia.

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[1] In cooperation with the Mid-Atlantic Food Processors Association, Inc., Easton, Md.; the Virginia Truck and Ornamentals Research Station, Norfolk, Va.; the Agricultural Experiment Station, University of Delaware, Newark, Del.; and the Sussex Soil and Water Conservation District, Georgetown, Del.

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SAMPLING AND ANALYTICAL PROCEDURES

Twenty processing plants were selected so that nine food products (listed chronologically by harvest schedule) were represented in the survey: peas, green beans, tomatoes, corn, lima beans, sweet potatoes, squash, poultry, and white potatoes. Although some of the plants processed more than one product, no more than one product was processed at any one time.

It was originally planned to take hourly "grab" samples from one or more processors on Tuesdays, Wednesdays, and Thursdays of two consecutive weeks of 1968. However, because weather conditions adversely affected harvesting schedules and because of occasional mechanical breakdowns, the plants were not always in operation during the periods when samples were to be collected. Therefore, it was not possible to obtain as many samples as originally planned. The number of samples actually collected in 1968 was 797. In 1967, 20 samples were collected and in 1969, 80 samples. Thus, the total number of samples was 897. Table 1 lists the products sampled, the number of days in which samples were collected, the number of samples collected from each plant, and the total number of samples collected for each of the nine food products. To insure anonymity, code letters are used for each of the cooperating plants.

Of the 897 samples collected, 830 represented waste water collected from 18 vegetable-processing plants. Sixty-seven waste water samples from the two cooperating poultry plants were also included so that the magnitude of variability in constituents of waste water from vegetable processing and from poultry processing could be compared.

In the food-processing industry, it is common practice to combine different waste water streams from different sources within an individual plant. The combined stream is then passed over a screen to remove the coarse solids. At all plants surveyed, the samples were taken after the waste water had passed through the screen. At a few plants, additional samples were also collected from individual waste water streams from specific sources of pollution within the plant.

The samples were collected in one-quart, plastic-coated milk cartons and were immediately frozen with dry ice in insulated ice chests, which were carried to the processing plants.[3] On Fridays, the collector with the frozen samples returned to the laboratory at Norfolk, Va., where the frozen samples were stored in freezers. Before being analyzed, the samples were quickly thawed in a warm bath, the contents were thoroughly mixed, and aliquots were removed with wide-tipped (3-mm.) volumetric pipettes. Particular care was taken to insure that the solids were completely in suspension when the aliquots were taken.

To facilitate comparison of this survey with previous studies reported from a variety of disciplines, the following analyses were made: pH; electrical conductivity (EC); dissolved solids, ash and chemical oxygen demand (COD);[4] total solids, ash and COD; total sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), chloride (Cl), and phosphorus (P). The oxygen demand was measured as COD rather than as biochemical oxygen demand (BOD) because the COD method is quicker and more reproducible. Dissolved solids, ash, and COD were not determined on the 1967 sweet potato and the 1968 pea and green bean waste water samples.

In general, all measurements were made in accordance with standard analytical procedures.[5]

The pH measurements were made with a glass electrode and the EC measurements with a conductivity bridge. The solids and ash contents of the samples were determined by gravimetric methods: the solids content represents the weight of material remaining in a procelain crucible after evaporation and drying at 105° C., and the ash content represents the weight of material remaining after ignition at 600° C. The same aliquot was used to determine both solids and ash. During the early part of the survey, the dissolved fraction was that part that passed through Whatman #1 filter paper supported on a modified Buchner funnel. Later, this procedure was changed and a Gelman filter apparatus fitted with Gelman Type A tared, fiberglass discs (47-mm.)[4] was used.

The cations and phosphorus were determined on an acid ($HNO_3 + HC10_4$) digest of an aliquot of the unfiltered raw material. Sodium and potassium were determined by flame emission and calcium and magnesium by atomic absorption spectrophotometry. Total P was measured by the vanadomolybdophosphoric yellow method.[6] Chloride was determined with a Cotlove automatic chloride titrator.

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[3] Fogarty, W. J., and Reeder, M. E. BOD data retrieval through frozen storage. Public Works 95 (3): 88-91. 1964.

Morgan, P. E., and Clarke, E. F. Preserving domestic waste samples by freezing. Public Works 95 (10): 73-75. 1964.

[4] American Public Health Association, American Water Works Association, and Water Pollution Control. Standard methods for the examination of water and wastewater. Ed. 12, 769 pp. New York. 1965. (In this report, the terms "solids" and "ash" correspond to the terms "residue" and "fixed residue" used in the referenced publication.)

[5] See footnote 4. Also, U.S. Department of the Interior. FWPCA methods for chemical analysis of water and wastes. Federal Water Pollution Control Administration Analytical Quality Control Laboratory. 280 pp. Cincinnati. 1969.

[6] Jackson, M. L. Soil chemical analysis. 498 pp. Englewood Cliffs, N.J. 1958.

Table 1.—Waste water samples (897) collected from 20 plants processing 9 food products during the years 1967-69

Plant code, frequency of sampling, and no. of samples	1967 waste water samples from sweet potatoes	1968 waste water samples from–								1969 waste water samples from–		
		Peas	Green beans	Tomatoes	Corn	Lima beans	Sweet potatoes	Squash	Poultry	Peas	Corn	White potatoes
A:												
No. of sample-collection days	—	—	—	—	5	—	—	—	—	—	—	—
No. of samples	—	—	—	—	29	—	—	—	—	—	—	—
B:												
No. of sample-collection days	—	6	—	—	5	6	7	—	—	3	—	3
No. of samples	—	35	—	—	29	[1]45	60	—	—	24	—	25
C:												
No. of sample-collection days	—	4	—	—	6	4	—	—	—	—	—	—
No. of samples	—	24	—	—	36	32	—	—	—	—	—	—
E:												
No. of sample-collection days	—	2	—	—	3	3	—	—	—	—	—	—
No. of samples	—	12	—	—	7	11	—	—	—	—	—	—
J:												
No. of sample-collections days	—	—	5	—	—	—	—	—	—	—	—	—
No. of samples	—	—	27	—	—	—	—	—	—	—	—	—
M:												
No. of sample-collection days	1	—	—	—	—	—	6	—	—	—	—	—
No. of samples	9	—	—	—	—	—	47	—	—	—	—	—
O:												
No. of sample-collection days	—	—	—	—	2	—	—	—	—	—	—	—
No. of samples	—	—	—	—	16	—	—	—	—	—	—	—
Q:												
No. of sample-collection days	1	—	—	2	—	—	—	—	—	—	—	—
No. of samples	11	—	—	16	—	—	—	—	—	—	—	—
S:												
No. of sample-collection days	—	3	—	—	—	—	—	5	—	—	—	—
No. of samples	—	15	—	—	—	—	—	40	—	—	—	—
T:												
No. of sample-collection days	—	2	—	—	—	—	—	—	—	—	—	—
No. of samples	—	8	—	—	—	—	—	—	—	—	—	—
U:												
No. of sample-collection days	—	—	6	—	—	—	—	—	—	—	—	—
No. of samples	—	—	44	—	—	—	—	—	—	—	—	—

Footnote at end of table.

Continued–

Table 1.—Waste water samples (897) collected from 20 plants processing 9 food products during the years 1967-69—Continued

Plant code, frequency of sampling, and no. of samples	1967 waste water samples from sweet potatoes	1968 waste water samples from—								1969 waste water samples from—		
		Peas	Green beans	Tomatoes	Corn	Lima beans	Sweet potatoes	Squash	Poultry	Peas	Corn	White potatoes
V:												
No. of sample-collection days	—	—	3	—	—	—	—	—	—	—	—	—
No. of samples	—	—	25	—	—	—	—	—	—	—	—	—
W:												
No. of sample-collection days	—	—	—	—	—	—	—	—	6	—	—	—
No. of samples	—	—	—	—	—	—	—	—	45	—	—	—
X:												
No. of sample-collection days	—	—	—	6	—	—	—	—	—	—	—	—
No. of samples	—	—	—	48	—	—	—	—	—	—	—	—
Y:												
No. of sample-collection days	—	—	—	6	—	—	—	—	—	—	—	—
No. of samples	—	—	—	50	—	—	—	—	—	—	—	—
Z:												
No. of sample-collection days	—	—	—	—	2	—	—	—	—	—	—	—
No. of samples	—	—	—	—	14	—	—	—	—	—	—	—
AA:												
No. of sample-collection days	—	—	—	—	—	—	6	—	—	—	—	—
No. of samples	—	—	—	—	—	—	45	—	—	—	—	—
BB:												
No. of sample-collection days	—	—	—	—	—	—	—	—	—	3	1	—
No. of samples	—	—	—	—	—	—	—	—	—	18	13	—
CC:												
No. of sample-collection days	—	—	—	—	—	—	—	—	3	—	—	—
No. of samples	—	—	—	—	—	—	—	—	22	—	—	—
DD:												
No. of sample-collection days	—	—	—	2	—	—	—	—	—	—	—	—
No. of samples	—	—	—	15	—	—	—	—	—	—	—	—
Total No. of samples	20	94	96	129	131	88	152	40	67	42	13	25

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[1] Includes 35 samples taken while all plant operations were in effect simultaneously and 10 samples taken during blanching, inspection, and freezing operations only.

RESULTS AND DISCUSSION

The analytical results of the measurements are presented in table 2 which gives data for each group of samples taken for a specific product processed by the cooperating plants. The values represent the mean of daily averages and the standard deviations indicate the degree of variability encountered from day to day.

The results indicate that the composition of waste water samples varies greatly for individual products, for different plants processing the same product, and for time of sampling–even for hour to hour intervals–in a single plant processing a single product.

For a single waste water constituent, the variability among products and among plants processing a single product is the result of the processing procedures employed. For example, potatoes can be peeled with either steam or lye solution. Peas and lima beans can be "graded" by means of a specific gravity method that uses a brine, usually made from sodium chloride (NaCl). All processing plants use a blancher to inactivate enzymes that cause spoilage; however, the blanching procedure may also involve steam or hot water. Periodically, the contents of the lye peeler, quality grader, or blancher are "dumped" into the waste stream. The result is a surge of sugars, starches, or salts into the stream. A single sample taken at the time that the surge occurs would give an erroneous impression of the average composition of the waste water.

A more detailed examination of these variabilities can be made from data in tables 2, 3, 4, and 5. With respect to the quality grader used in the processing of peas and lima beans, the brine concentration ranges from 6.5 to 11.5 percent NaCl for peas and from 9 to 19 percent NaCl for lima beans. The results of the higher brine concentration required for processing lima beans may be seen by comparing the EC or sodium concentrations in the waste water from plant B when peas and lima beans were processed (table 2). Plant B sometimes uses a quality grader, but plant C does not. The major difference in the sodium values for the two plants is reflected in the standard deviation of the daily means (tables 3 and 4). It can be seen that the large deviation of plant B was the result of widely erratic (and sometimes very high) sodium concentrations on June 18 and 20. Table 3 also shows the irregularities in processing schedules. Plant B operated on June 11, 13, and 19 but plant C did not; plant C operated on June 21, but plant B did not. Such unpredictable interruptions in processing interfere with preplanned sampling schedules. The average sodium concentration was higher at plant E than at any other plant processing peas. During the lima bean season, it was observed that there was an almost continual loss of brine over the side walls of the quality grader. Assuming that the same situation existed during the pea season, such continual spillage of brine throughout the day could cause high sodium and chloride values in the waste water at plant E.

Plant B is a freezer operation. The lima beans processed by this plant can be held for a period in ice after they have been washed, graded, and screened for size; and before they are blanched, inspected, and frozen. In table 2, the first horizontal row of values for lima beans, plant B, shows the composition of the waste water when all operations are in effect simultaneously. The second horizontal row of values for plant B shows the composition of the waste water during the blanching, inspection, and freezing operations only. Table 2 indicates that the values for EC, solids, ash, sodium, and chloride increase when the washing, grading, and screening operations are included. This suggests that the quality grader is the principal source of salts (NaCl) in the waste water and the blancher is the principal source of COD.

The compositions of white and sweet potato waste waters are given S in table 2. Plant Q lye-peels sweet potatoes following a hot water wash, plants M and AA lye-peel without a hot water wash, and plant B steam-peels sweet and white potatoes. Of all the waste waters investigated, those from lye-peeling operations present the biggest disposal problems from the pollution aspect.

Table 2 also indicates that the sodium concentration in the waste water was lower at plant Q than at either of the other plants (M and AA) that used the lye-peeling process. This variation is probably related to the condition of the product being processed as well as to the procedure employed. The concentration and temperature of the lye and the detention time in the peeler are adjusted according to skin toughness. At plant Q, the hot water wash procedure softens the skin and removes some of the adhering soil before the potatoes go into the peeler. When the waste water samples were taken, plant Q was processing sweet potatoes recently dug from fields in the vicinity of the plant whereas plant M was processing sweet potatoes trucked in from outside the Mid-Atlantic area. The longer the time from digging to processing, the tougher the skin becomes and the greater the concentration of lye required in the peeler. The lye concentration in the peeler may vary from 7 to 12 percent.

The standard deviation for sodium at plant Q greatly exceeds the mean. This result can be explained by the composition of the individual samples taken through the day (table 5). For example, before the 12:30 sample of waste water was taken, the sample collector noted that the lye peeler was being emptied. A sample from the lye peeler was therefore taken at 12:20 and the composition of this latter sample is presented at the bottom of table 5.

Table 2.–Composition of waste water samples (897) collected from 20 plants processing 9 food products in 1967-69

Product sampled, year of sampling, and plant code	Frequency of sampling	Samples collected	Waste water constituents[1]					
			pH	Elect. conductivity	Solids		Ash	
					Dissolved[2]	Total	Dissolved[2]	Total
	Days	*No.*		*Mmho/cm.*	*Mg./l.*	*Mg./l.*	*Mg./l.*	*Mg./l.*
Peas:								
1968–								
B	6	35	5.3 ± 0.1	1.1 ± 0.8	N.D.	1,043 ± 438	N.D.	477 ± 324
C	4	24	7.0 ± 0.6	0.8 ± 0.1	N.D.	1,760 ± 649	N.D.	400 ± 54
E	2	12	5.7 ± 0.1	4.7 ± 0.1	N.D.	3,936 ± 443	N.D.	2,413 ± 61
S	3	15	5.4 ± 0.2	1.9 ± 1.3	N.D.	1,999 ± 854	N.D.	828 ± 594
T	2	8	6.3 ± 0.1	3.7 ± 1.3	N.D.	3,225 ± 980	N.D.	1,611 ± 301
1969–								
B	3	24	6.3 ± 0.1	0.9 ± 0.2	1,163 ± 236	1,244 ± 266	510 ± 167	526 ± 184
BB	3	18	4.9 ± 0.1	1.2 ± 0.4	1,410 ± 269	1,509 ± 268	710 ± 194	722 ± 202
Green beans, 1968:								
J	5	27	6.5 ± 0.3	1.2 ± 0.2	N.D.	1,181 ± 197	N.D.	566 ± 126
U	6	44	5.5 ± 0.1	0.4 ± 0.1	N.D.	751 ± 119	N.D.	238 ± 70
V	3	25	5.2 ± 0.1	0.2 ± 0.1	N.D.	252 ± 27	N.D.	25 ± 21
Squash, 1968:								
S	5	40	5.6 ± 0.4	0.2 ± 0.1	305 ± 128	363 ± 127	96 ± 52	111 ± 55
Tomatoes, 1968:								
Q	2	16	5.6 ± 1.1	1.1 ± 0.3	2,326 ± 1,172	2,694 ± 1,433	522 ± 175	547 ± 240
X	6	48	4.5 ± 0.1	1.4 ± 0.1	5,041 ± 454	5,746 ± 517	821 ± 106	1,136 ± 181
Y	6	50	4.7 ± 0.1	1.4 ± 0.2	4,976 ± 938	6,037 ± 1,438	804 ± 165	1,017 ± 219
DD	2	15	5.2 ± 0.3	0.6 ± 0.1	1,578 ± 66	1,877 ± 54	364 ± 31	420 ± 43
Corn:								
1968								
A	5	29	7.1 ± 0.2	0.8 ± 0.1	3,816 ± 406	4,403 ± 489	344 ± 96	387 ± 104
B	5	29	5.7 ± 0.3	0.4 ± 0.1	2,765 ± 631	3,420 ± 423	217 ± 89	237 ± 91
C	6	36	6.8 ± 0.6	0.9 ± 0.1	7,137 ± 1,207	8,183 ± 1,552	484 ± 50	509 ± 30
I	3	7	6.2 ± 0.2	0.8 ± 0.1	7,380 ± 1,786	8,643 ± 1,413	443 ± 130	486 ± 142
O	2	16	8.0 ± 0	0.6 ± 0.1	1,169 ± 197	1,399 ± 382	256 ± 14	277 ± 6
Z	2	14	6.4 ± 0.1	0.6 ± 0	2,507 ± 291	2,886 ± 124	203 ± 30	233 ± 38
1969								
BB	1	13	5.2 ± 0.7	0.2 ± 0.1	2,636 ± 1,213	3,227 ± 1,435	192 ± 119	192 ± 119
Lima beans, 1968:								
B[3]	6	35	5.8 ± 0.3	5.0 ± 1.0	3,447 ± 1,308	3,665 ± 1,304	2,775 ± 1,298	2,805 ± 1,243
B[4]	3	10	5.7 ± 0.7	1.0 ± 0.5	996 ± 189	1,070 ± 233	369 ± 158	391 ± 158
C	4	32	7.0 ± 0.2	0.7 ± 0	998 ± 190	1,158 ± 185	340 ± 76	379 ± 83
E	3	11	6.0 ± 0.1	3.0 ± 1.9	3,334 ± 513	3,253 ± 184	1,979 ± 193	2,120 ± 298
Sweet potatoes:								
1967–								
M	1	9	11.4 ± 0.2	33.0 ± 10.8	N.D.	33,887 ± 7,124	N.D.	16,512 ± 5,006
Q	1	11	10.5 ± 0.8	8.6 ± 19.9	N.D.	9,864 ± 7,876	N.D.	4,200 ± 6,567
1968								
M	6	47	10.7 ± 0.3	15.4 ± 4.2	25,656 ± 4,581	37,675 ± 4,728	9,961 ± 3,512	11,725 ± 3,343
AA	6	45	9.9 ± 0.3	10.9 ± 2.1	19,543 ± 2,345	24,647 ± 2,390	6,473 ± 1,164	7,786 ± 1,116
B	7	60	5.8 ± 0.2	0.4 ± 0.1	1,781 ± 178	3,017 ± 417	133 ± 32	277 ± 171
White potatoes, 1969:								
B	3	25	6.4 ± 0.2	0.7 ± 0.1	730 ± 110	1,930 ± 247	235 ± 125	237 ± 123
Poultry, 1968:								
W	6	45	7.5 ± 0.4	0.5 ± 0.1	526 ± 74	853 ± 54	97 ± 47	100 ± 44
CC	3	22	6.3 ± 0.2	0.4 ± 0.2	533 ± 222	738 ± 195	62 ± 55	62 ± 55

[1] Variabilities expressed as standard deviation of daily means.

[2] N.D. = Not determined.

[3] All operations simultaneously.

[4] Blanching, inspection, and freezing operations only.

Table 2.–Composition of waste water samples (897) collected from 20 plants processing 9 food products in 1967-69 Continued

Product sampled, year of sampling, and plant code	Waste water constituents[1]							
	COD		Na	K	Ca	Mg	Cl[2]	P[2]
	Dissolved[2]	Total[2]						
	Mg./l.	*Mg./l.*	*Meq./l.*	*Meq./l.*	*Meq./l.*	*Meq./l.*	*Meq./l.*	*Mg./l.*
Peas:								
1968–								
B	N.D.	534 ± 178	7.6 ± 10.4	0.3 ± 0.2	1.0 ± 0.1	0.9 ± 0.2	9.9 ± 11.1	3.3 ± 1.3
C	N.D.	1,517 ± 665	5.5 ± 0.8	1.2 ± 0.8	0.6 ± 0.1	1.4 ± 0.4	0	7.2 ± 2.9
F	N.D.	1,680 ± 738	41.7 ± 3.2	2.3 ± 1.0	0.9 ± 0	1.5 ± 0.6	44.4 ± 2.0	9.1 ± 4.1
S	N.D.	985 ± 415	12.9 ± 10.2	0.9 ± 0.4	0.8 ± 0.3	0.6 ± 0.2	20.3 ± 18.5	3.7 ± 1.5
T	N.D.	1,295 ± 214	31.7 ± 14.8	1.5 ± 0.6	1.7 ± 0.5	2.1 ± 0.3	31.8 ± 14.1	6.6 ± 3.0
1969–								
B	568 ± 268	625 ± 290	11.6 ± 4.1	0.7 ± 0.2	0.6 ± 0.1	0.6 ± 0.1	8.7 ± 2.6	2.5 ± 0.4
BB	650 ± 123	767 ± 225	13.8 ± 5.2	0.9 ± 0.2	0.6 ± 0.2	0.3 ± 0	11.1 ± 4.0	4.2 ± 0.2
Green beans, 1968:								
J	N.D.	503 ± 98	9.7 ± 1.6	0.7 ± 0.2	1.8 ± 2.1	1.5 ± 0.3	6.5 ± 1.6	1.0 ± 0.4
U	N.D.	736 ± 239	1.6 ± 0.3	0.7 ± 0.2	0.7 ± 0.1	1.3 ± 0.1	0.1 ± 0.2	1.3 ± 0.8
V	N.D.	183 ± 38	0.7 ± 0.1	0	0.5 ± 0.1	0.6 ± 0.1	0	0.4 ± 0.1
Squash, 1968:								
S	244 ± 152	286 ± 129	0.9 ± 0.3	0.2 ± 0.2	0.5 ± 0.1	0.7 ± 0.2	0	0.9 ± 0.7
Tomatoes, 1968:								
Q	1,572 ± 2,009	3,151 ± 1,978	5.7 ± 1.4	3.6 ± 2.3	1.8 ± 0.3	1.8 ± 0.5	4.6 ± 0.4	14.3 ± 6.9
X	5,983 ± 530	6,417 ± 524	0.4 ± 0.1	10.4 ± 1.0	1.3 ± 0.2	3.3 ± 0.2	0.2 ± 0.3	30.7 ± 5.4
Y	5,803 ± 1,112	6,440 ± 1,293	0.4 ± 0.1	9.9 ± 2.5	3.0 ± 0.2	3.4 ± 0.5	1.1 ± 1.0	26.4 ± 4.3
DD	1,628 ± 149	1,992 ± 127	0.6 ± 0	2.1 ± 0.3	2.3 ± 0.1	1.2 ± 0.1	0.4 ± 0.6	8.2 ± 2.1
Corn:								
1968–								
A	4,369 ± 546	6,457 ± 623	4.0 ± 1.1	1.0 ± 0.2	1.8 ± 0.2	1.8 ± 0.3	2.6 ± 1.8	11.3 ± 2.4
B	3,493 ± 1,198	5,215 ± 1,520	0.9 ± 0.2	1.1 ± 0.4	0.6 ± 0.2	1.5 ± 0.7	0	12.8 ± 3.5
C	7,527 ± 1,221	11,770 ± 1,667	4.7 ± 1.7	2.2 ± 0.7	0.6 ± 0.3	1.5 ± 0.4	0	27.4 ± 3.3
E	7,914 ± 2,110	10,505 ± 492	3.0 ± 0.9	2.7 ± 0.5	0.5 ± 0.3	1.4 ± 0.6	2.1 ± 1.8	22.7 ± 8.2
O	1,052 ± 324	1,294 ± 467	2.7 ± 0.2	0.3 ± 0.2	1.4 ± 0.1	1.6 ± 0.1	0	4.6 ± 2.1
Z	2,106 ± 101	2,445 ± 4	4.6 ± 0.1	0.5 ± 0	0.9 ± 0.2	0.7 ± 0.3	0	7.0 ± 0.2
1969–								
BB	2,868 ± 1,327	3,491 ± 1,610	0.4 ± 0.1	1.5 ± 0.7	0.4 ± 0.1	0.5 ± 0.1	0	8.8 ± 5.5
Lima beans, 1968								
B[3]	474 ± 112	624 ± 87	69.9 ± 76.9	1.0 ± 0.4	2.2 ± 1.2	1.5 ± 0.7	43.7 ± 29.5	2.8 ± 2.3
B[4]	504 ± 115	575 ± 116	5.8 ± 2.2	0.9 ± 0.3	1.3 ± 0.8	1.3 ± 0.5	6.7 ± 8.7	2.2 ± 0.9
C	609 ± 79	742 ± 104	5.1 ± 0.5	0.8 ± 0.2	1.1 ± 0.2	1.1 ± 0.2	0.4 ± 0.4	3.2 ± 0.8
I	985 ± 7	1,243 ± 39	31.3 ± 3.0	1.8 ± 0.2	1.2 ± 0.1	1.4 ± 0	45.1 ± 10.2	5.1 ± 2.3
Sweet potatoes:								
1967–								
M	N.D.	N.D.	222 ± 84	27.8 ± 34.4	3.6 ± 1.7	3.5 ± 0.8	N.D.	N.D.
O	N.D.	N.D.	67.3 ± 127	3.7 ± 1.8	2.4 ± 1.0	2.7 ± 1.4	N.D.	N.D.
1968–								
M	14,543 ± 1,817	32,903 ± 5,122	197 ± 64	10.4 ± 1.4	2.8 ± 1.6	3.6 ± 0.7	5.9 ± 0.6	40.2 ± 7.4
AA	12,724 ± 1,552	22,673 ± 2,494	136 ± 14	7.0 ± 0.7	3.2 ± 0.6	3.1 ± 0.5	13.1 ± 0.7	30.6 ± 5.1
B	1,743 ± 187	3,822 ± 835	2.2 ± 0.6	1.1 ± 0.2	0.8 ± 0.1	1.2 ± 0.1	.8 ± 1.2	5.9 ± 1.1
White potatoes, 1969.								
B	295 ± 49	1,161 ± 724	5.3 ± 1.1	1.5 ± 0.2	4.0 ± 4.0	1.3 ± 0.5	4.8 ± 0.5	5.4 ± 0.9
Poultry, 1968:								
W	339 ± 27	902 ± 51	1.5 ± 0.5	0.7 ± 0.1	1.5 ± 0.6	0.7 ± 0.1	8.3 ± 0.9	3.9 ± 0.8
CC	275 ± 75	795 ± 75	1.8 ± 0.6	0.4 ± 0.2	1.8 ± 0.1	0.6 ± 0.2	9.3 ± 1.8	5.1 ± 1.9

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[1] Variabilities expressed as standard deviation of daily means.

[2] N.D. = Not determined.

[3] All operations simultaneously.

[4] Blanching, inspection, and freezing operations only.

Table 3.–Daily sodium concentrations in waste samples from plants B and C during processing of peas in 1968

Date	Sodium concentration[1]	
	Plant B	Plant C
	Meq./l.	*Meq./l.*
June 11	0.8 ± 0.1	—
June 12	—	—
June 13	2.8 ± 0.5	—
June 14	3.7 ± 0.8	6.6 ± 0.3
June 18	15.9 ± 17.0	5.1 ± 1.2
June 19	4.9 ± 2.5	—
June 20	16.3 ± 12.8	4.8 ± 0.2
June 21	—	5.7 ± 0.2

[1] Variabilities expressed as standard deviation of individual measurements.

Table 4.–Hourly sodium concentrations in waste water samples from plant B during processing of peas on June 18 and 20, 1968

Date and hour	Na
	Meq./l.
June 18:	
1430	2.6
1520	11.5
1610	12.8
1700	10.5
1740	49.7
2000	8.1
June 20:	
1105	2.4
1215	32.8
1300	10.0
1420	30.0
1515	5.0
1615	17.8

Table 5.–Composition of waste water measured hourly at plant Q during processing of sweet potatoes (lye-peeled), November 1, 1967

Hour	pH	Elect. conductivity	Total Solids	Total ash	Na	K	Ca	Mg
		Mmho/cm.	*Mg./l.*	*Mg./l.*	*Meq./l.*	*Meq./l.*	*Meq./l.*	*Meq./l.*
0830	10.5	2.4	8,752	1,948	26.0	3.5	2.4	2.4
0930	9.5	1.4	2,604	1,220	9.7	1.1	1.6	1.8
1030	10.7	2.5	9,188	4,056	26.7	3.7	2.1	3.5
1130	8.5	1.2	1,724	660	85.0	1.0	1.6	1.7
1230	11.1	68.6	31,404	23,704	445.0	4.0	5.0	3.1
1330	10.7	2.6	11,268	4,404	0.6	4.0	2.0	6.5
1430	11.1	3.9	10,100	1,920	35.0	5.6	3.2	2.0
1530	10.9	2.5	5,664	1,608	22.0	3.1	2.0	1.6
1630	10.9	3.1	9,640	2,076	30.0	4.7	1.9	2.8
1730	10.3	2.0	6,363	1,704	18.0	2.9	2.0	1.9
1830	11.2	4.5	11,976	2,908	41.0	7.1	2.6	2.6
	Contents of lye-peeler							
1220	11.2	62.4	78,672	38,092	676	29.0	18.0	7.7

Since about 1969, some processors of white potatoes have begun using the so-called dry lye-peel method,[7] which minimizes the volume of water involved and greatly reduces the amount of peels or caustic in the waste water. So far, this method has not been used to peel sweet potatoes.

Poultry processing does not require the use of the corrosive caustic, salt brine, and blanching water used in vegetable processing. Therefore, poultry processing does not require the periodic dumping of plant tanks and vats. As a result, samples of poultry-processing waste water should be much less variable than samples of vegetable-processing waste water. To measure the magnitude of variation between the two types of waste water, the 67 poultry-processing samples were also analyzed. The analytical results (table 2) indicated that the standard deviations for all constituents of the poultry-processing samples measured were much smaller than the standard deviations for the vegetable-processing constituents.

In spite of the great degree of variability (hour to hour, day to day, plant to plant) in the values reported, a "product average" was calculated from the daily means and is presented in table 6. With the exceptions of steam-peeled sweet potatoes and poultry, the products listed in table 6 are arranged in order of total COD values, which increase from top to bottom in the vertical columns. None of the other constituents follow the same sequence.

Table 6 indicates that the waste water from plants processing tomatoes, corn, and lye-peeled sweet potatoes are generally highest in solids and COD. This finding is attributed to the skins and underlying tissue of tomatoes and sweet potatoes and to the starches and sugars from corn and potatoes. The waste water from plants processing peas, lima beans, and lye-peeled sweet potatoes are highest in electrical conductivity and sodium. This finding is attributed to the salt brine (NaCl) in the quality grader used for the peas and lima beans and to the lye (NaOH) used for peeling the sweet potatoes. Table 6 also indicates that waste water from plants processing tomatoes is relatively high in potassium and phosphorus, whereas waste water from white potato processing is higher in calcium than waste water from any other product investigated.

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[7] Graham, R. P., Huxsoll, C. C., Hart, M. R., and others. "Dry" caustic peeling of potatoes. Food Technology 23:61. 1969.

Table 6.–Average composition of waste water samples (897) from plants processing 9 food products in 1967-69[1]

No. of plants sampled and products processed	pH	Elect. con-duc-tivity	Solids		Ash		COD		Na	K	Ca	Mg	Cl	P
			Dis-solved	Total	Dis-solved	Total	Dis-solved	Total						
		Mmhos/ cm.	*Mg./ l.*	*Mg./ l.*	*Mg./ l.*	*Mg./ l.*	*Mg./ l.*	*Mg/ l.*	*Meq./ l.*	*Meq/ l.*	*Meq./ l*	*Meq./ l.*	*Meq/ l.*	*Mg./ l.*
1, Squash	5.6	0.2	305	363	96	111	244	286	0.9	0.2	0.5	0.7	0.0	0.9
3, Green beans	5.8	0.6	—	798	—	306	—	534	4.3	0.6	1.0	1.2	2.4	1.0
4, Lima beans	6.1	2.8	2,354	2,474	1,566	1,617	609	760	34.4	1.1	1.6	1.3	26.2	3.2
7, Peas	5.8	1.7	—	1,820	—	815	—	972	14.3	0.9	0.8	0.9	14.4	4.8
1, White potatoes, steam-peeled	6.4	0.7	730	1,930	235	237	295	1,161	5.3	1.5	4.0	1.3	4.8	5.4
4, Tomatoes	4.8	1.3	4,244	4,990	720	928	4,820	5,464	1.1	8.3	2.1	2.9	1.1	24.2
7, Corn	6.6	0.7	4,493	5,247	340	1,368	4,891	7,144	3.2	1.5	0.9	1.5	0.8	16.0
1, Sweet potatoes, steam-peeled	5.8	0.4	1,781	3,071	133	277	1,743	3,822	2.2	1.1	0.8	1.2	0.8	5.9
4, Sweet potatoes, lye-peeled	10.3	9.5	22,600	29,830	8,216	9,840	13,633	27,383	163.0	9.7	3.0	3.3	9.5	35.4
2, Poultry	7.1	0.5	181	815	85	87	318	866	1.6	0.6	1.6	0.7	8.6	4.3

[1] Data for all samples of each product are arranged without regard for hour, day, or year of sampling, or for processing plant from which collected.